APPENDIX B

SOIL BEARING VALUES and SOIL LOAD TESTS

Introduction

In the case of bridge foundation design, determining the supporting capacity of a given foundation material with sufficient accuracy to ensure an adequate structural design requires a complete foundation investigation by an experienced and capable engineering geologistor soils engineer. Fortunately, however, the sophisticated approach to foundation design which is required for permanent work is generally unnecessary for falsework, because in most falsework designs maximum footing pressure is applied for only a short period of time and relatively greater settlements may be tolerated.

The Standard Specifications include a provision which requires the contractor to demonstrate by suitable load tests that the soil bearing values assumed in the falsework design do not exceed the supporting capacity of the soil. This requirement is included in the specifications to further ensure the adequacy of the falsework foundation, and the engineer should not hesitate to order a soil load test if he has doubt as to the ability of the foundation material to support the falsework loads. Note, however, that soil bearing capacity may in most cases be determined with sufficient accuracy for falsework design purposes by simple, static load tests performed by the contractor's forces. Ordinarily, it will not be necessary to employ the services of a private soils lab or consultant.

The following information has been prepared to assist the engineer in those situations where a load test is necessary to verify assumed soil bearing values.

General Information

Soil load tests should be made at the location where falsework will be erected. Bearing pads for the test load should be set on the same material as the falsework footing, and soil moisture content should approximate the content expected during falsework use.

Other factors being equal, the larger the bearing area of the test load pad, the more reliable the results. Pad area should be not less than two square feet in any case, and preferably three square feet or more in silty or clayey material.

A load test made on a relatively weak soil, such as clay or silt, will demonstrate the bearing capacity of the surface strata satisfactorily. More care should be taken in the test where small footings axe used as these are more critical than larger footings in this type of soil.

A load test made on a thick layer of granular soil overlying a thin weak soil will demonstrate the capacity of the upper layer. It will tell little of the capacity of the lower layer since the test load is small and the pressure on the lower area may be almost negligible since it is spread over a large area.

The effect of a unit-load on a small area may not correspond to the effect of the same unit-load on a large area.

A short-time load on a plastic soil may not have the same effect as the same unit-load on a large area of longer time duration, This is not true, however, for firm granular soils, as time does not not affect this type of soil.

Load Test Procedure

As provided in the specifications, the contractor is responsible for load test performance. The engineer, however, must determine the suitability of the proposed test for the given site conditions and evaluate the test results.*

To ensure uniformity, a "suitable" load test as this term is used in the specifications will be interpreted as meaning a test in which both settlement and duration of load are considered.

One simple and satisfactory test method is to apply a gradually-increasing load with respect to a fixed time interval, and to record the settlement at the end of each time period, The soil yield point is reached when a small increase in load produces a large increase in settlement. The load at yield point should be divided by a factor of safety of two to determine the allowable bearing value.

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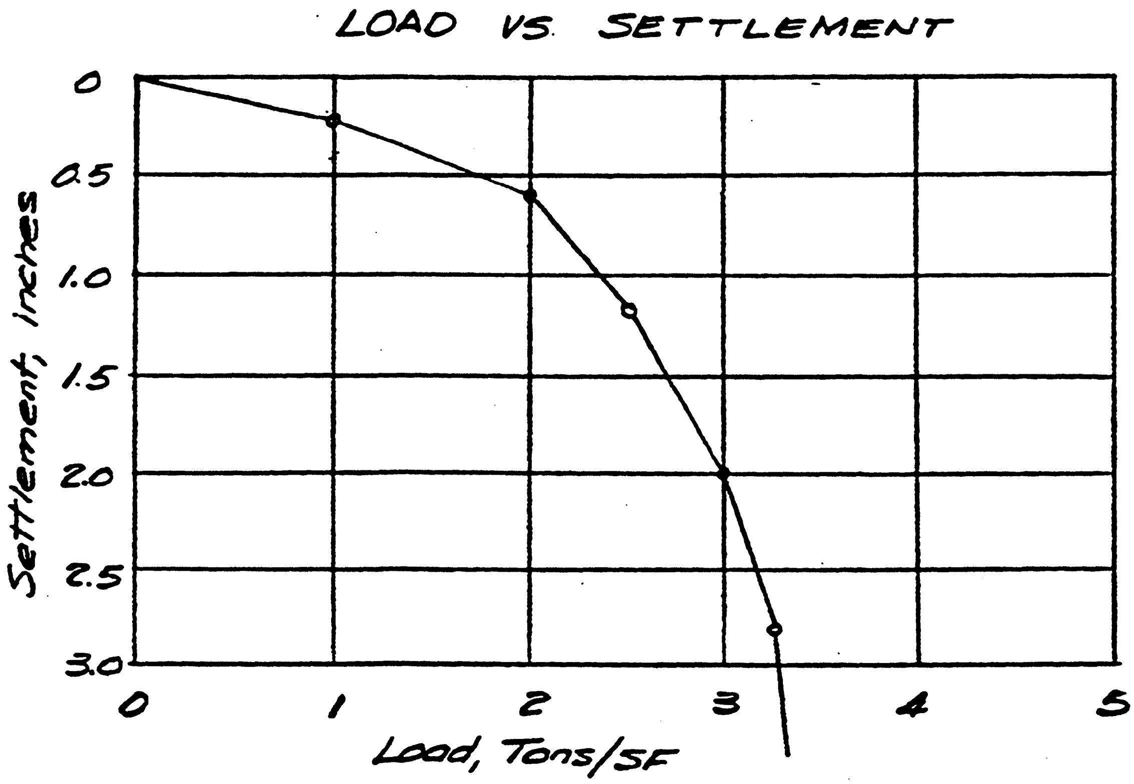
* The Division's Engineering Geology Branch is available for consultation and advice as to the suitability of load tests in a given field situation, as well as interpretation of test results.

SOIL LOAD TESTS

As an example, consider the following test in which the test load was increased every 12 hours over a three-day period.

Time Interval	Total Time	Load (T/SF)	Settlement (Inches)
12 hrs.	12 hrs.	1.0	0.2
12 hrs.	24 hrs.	2.0	0.6
12 hrs.	36 hrs.	2.5	1.2
12 hrs.	48 hrs.	3.0	2.0
12 hrs.	60 hrs.	3.25	2.8
4 hrs.	64 hrs.	3.50	4+

Load test results should be plotted as shown in the following load-settlement diagram.



Tram the diagram it is evident that the soil yield point is about 3.0 tons per square foot. This value should be divided by a factor of safety of 2.0 to determine the soil bearing value at the ground surface, which in this case is about 1.5 tons per square foot.

If no clearly-defined yield point exists, as will be the case in granular materials, the load which produces a one-inch settlement may be taken as the ultimate bearing capacity. Again, this value should be divided by a 2.0 safety factor to determine the allowable bearing value.

Another method takes into consideration the ratio of the size of the test pad to the size of the proposed falsework pad, along with the contractor's anticipated settlement. In this method the general formula for determining the total load which may be supported by a given -soil is expanded to include perimeter shear, as shown by the following relationship:

$$W = Ap = An + Pm$$

In the formula, W is the total load in pounds, A is the pad area in square feet, p is the allowable soil bearing value in pounds/ square foot, P is the pad perimeter in feet, n is the compressive stress (psf) on the soil column directly beneath the pad, and m is the Perimeter shear in pounds/lineal foot.

If the ratio of perimeter (P) to the area (A) is (x) then:

$$p = W/A = mx + n$$

Values of m and n are found by test loading two or more plates having different areas and perimeters. The load which produces the contractor's assumed pad settlement is taken as the allowable stress.

As an example, determine the bearing capacity of a 10-foot square footing if the contractor's proposed pad settlement is one-half inch.

Take two test pads, one two feet square and one three feet square. The smaller supported 25,200 pounds at one-half inch settlement. The larger, 39,700 pounds at the same settlement.

	W	A	P	
Smaller	25,200 lbs	4 SF	8 LF	25,200 = 4n + 8m
Larger	39,700 lbs	9 SF	12 LF	39,700 = 9n + 12m

Solving for (m) and (n), m = 2840 lbs/LF and n = 620 psf. For the actual footing, (x) = 40/100 = 0.4. By substituting values of (m), (n) and (x) into the equation p = mx + n, the allowable soil bearing value, p, = 2840(0.4) + 620 = 1755 psf.

Investigating of Underlying Weak Strata

Test results, as discussed thus far, give only an indication of the allowable soil bearing values at the surface. If a weak underlying strata exists, as indicated in the log of test borings, consideration should be given as to whether this strata will support the actual falsework load without excessive settlement.

An assumption can be made that the load is spread with depth on a l:2 slope as shown in Figure 1, which also shows a typical boring diagram.

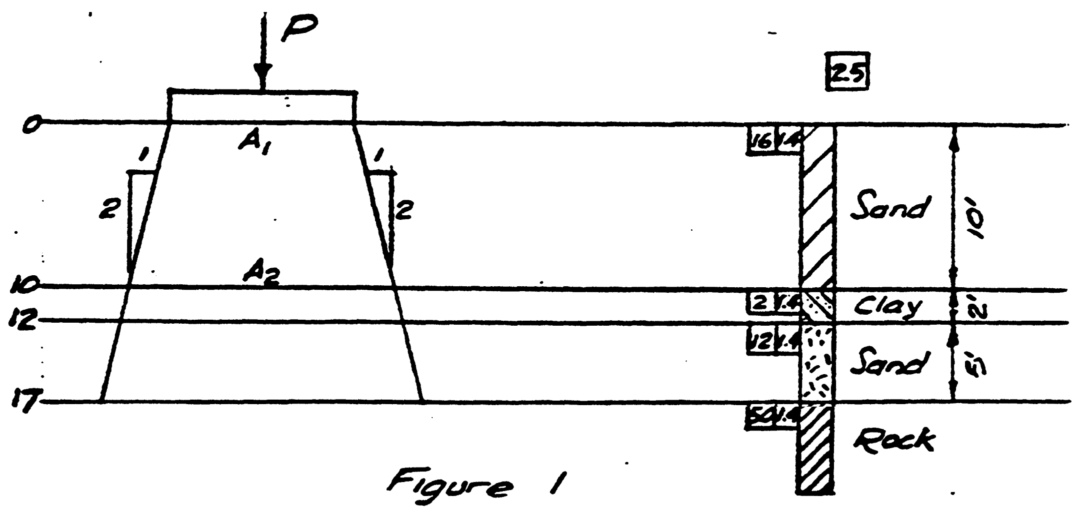


Figure 1

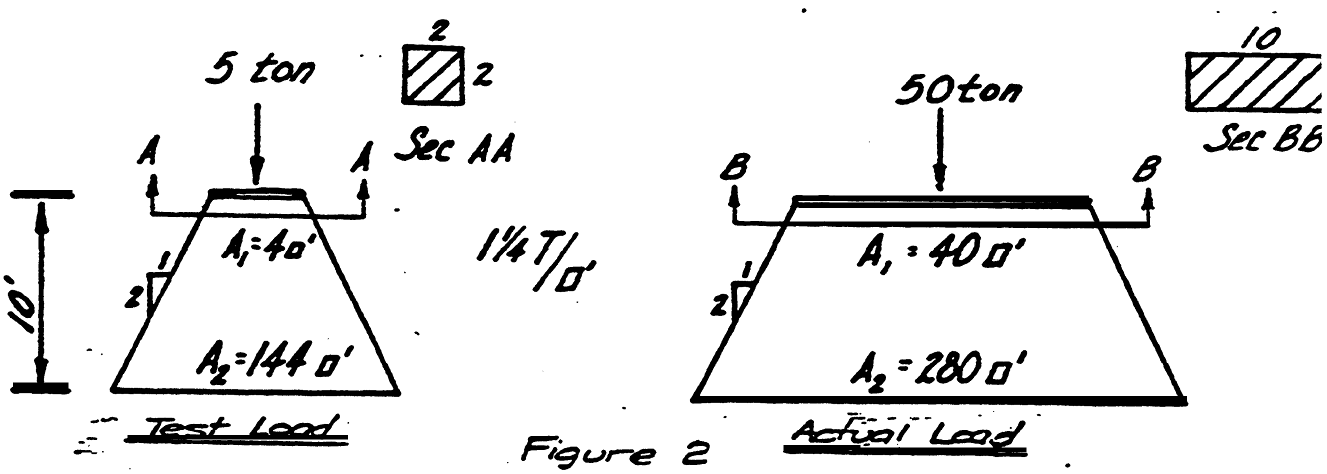


Figure 2

As can be seen, in Figure 2, the soil pressure at the surface is l-l/4 tons/square foot for both the test and the actual falsework pad. The pressure on the weak underlying strata in the test load is 0.035 tons/square foot, a reduction of 36:l due to load spreading. In the actual condition the pressure is 0.18 ton/square foot, a reduction of only 7:l, and this pressure may be more than the strata can safely support.

To help the engineer in his analysis, charts showing allowable soil pressure for clay and sandy soils are reproduced on the following two pages. These charts may be used to give a genera1 idea of the allowable bearing, based on soil classification.

Settlement

With the current emphasis on limited settlement of falsework, the engineer must be able to assess the probability that a given settlement, as predicted by the contractor, will actually occur. Some general statements may help in predicting these settlements.

1. Granular Material

   The maximum settlement will occur under the load as it is applied, and is usually small in magnitude.

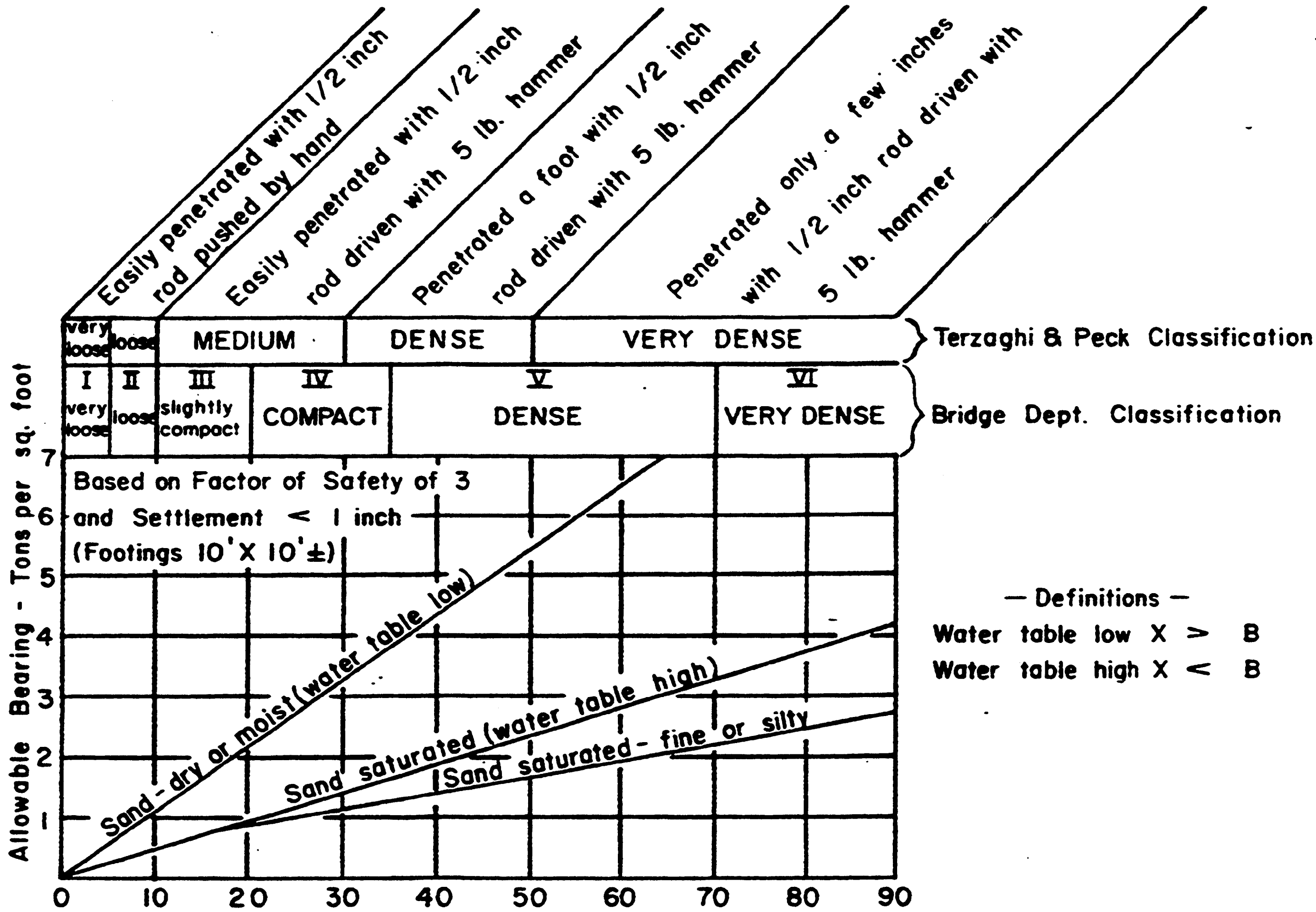
2. Silt and Fine Sand

   A large part occurs as the load is applied. More occurs as the water is squeezed out under long-term loading. If the water table rises, a “quick” condition may result with floatation of the fine grains and a resulting settlement increase at this later date.

3. Clay

   Again, part of the consolidation occurs as the load is applied, but the rate of consolidation decreases with time. Settlement my also occur due to drying out of clay in the summer. All settlement is due to a squeezing out or loss of moisture in the clay.

ALLOWABLE BEARING ON SANDY SOILS

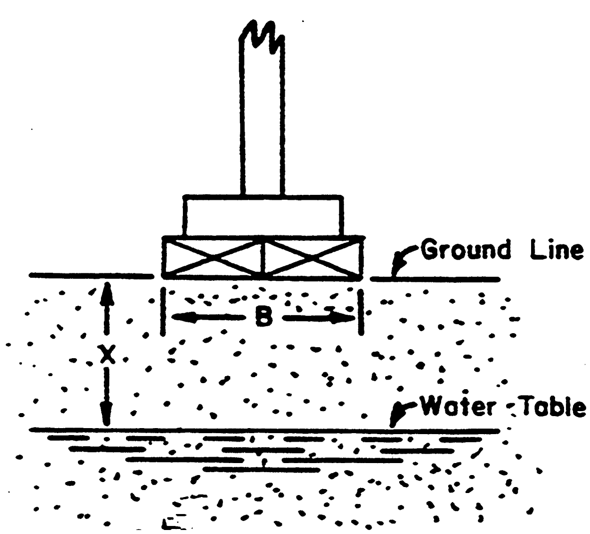


Number of Blows per Foot, 1.4 inch Sampler, 140 lb. Hammer, 30 inch fall
(For 5'X 5' footing allowable bearing may be increased 10 %)

— Definitions —

Water table low X > B

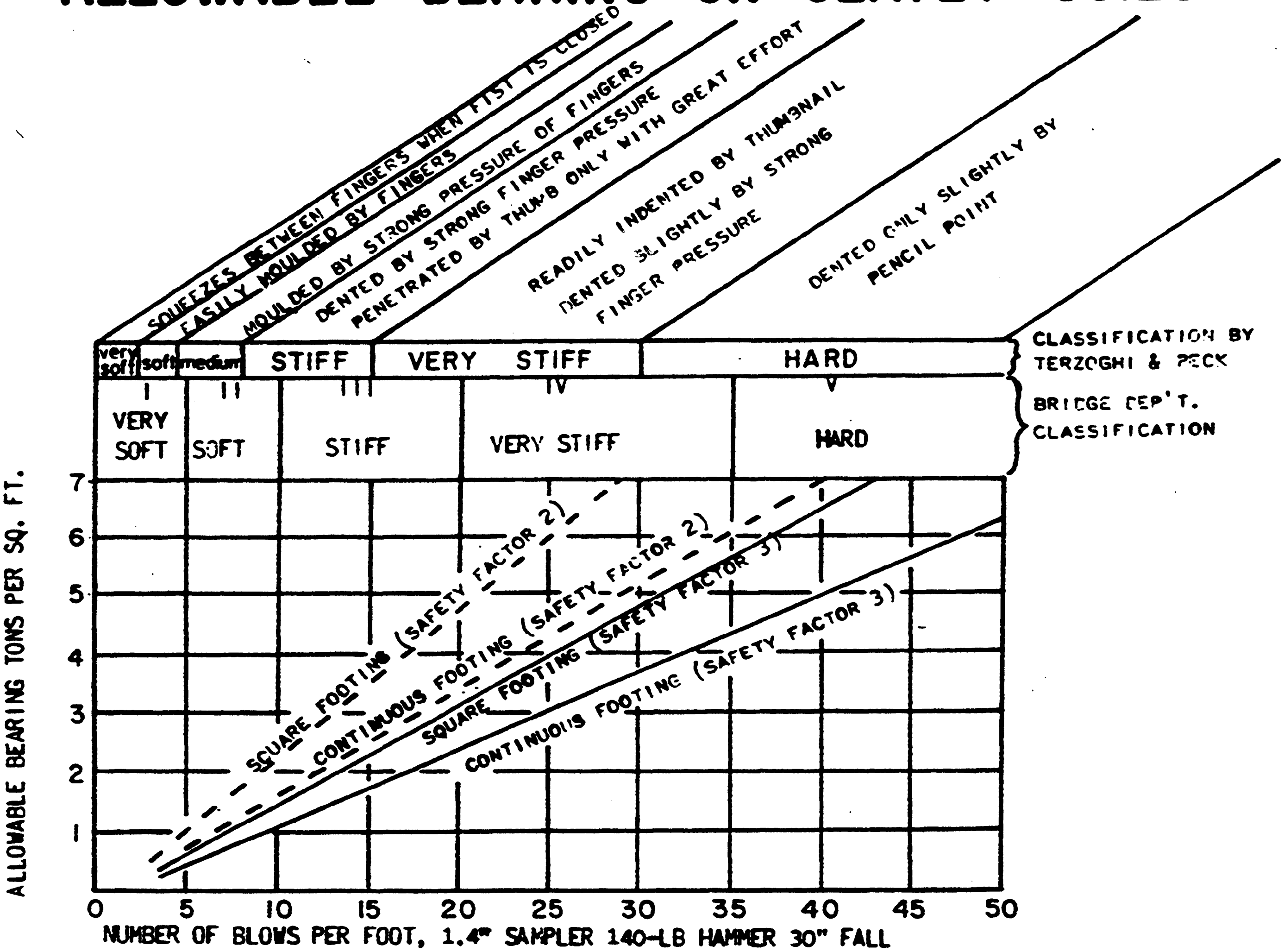
Water table high X < B



Major matters affecting bearing capacity

1) Position of water table
2) Relative density of sand
3) Width of footing "B"

ALLOWABLE BEARING ON CLAYEY SOILS



BEARINGS AS GIVEN ABOVE WILL GENERALLY BE CONSERVATIVE FOR CLAYEY SOILS.

WEAK STRATA AT SOME DISTANCE BELOW FOOTINGS MAY IN CASES CAUSE MORE SETTLEMENT THAN SOIL LAYERS IMMEDIATELY BELOW THE FOOTINGS.

FOR SAME UNIT PRESSURE, LARGE FOOTINGS SETTLE MOST. THIS IS PARTICULARLY SO WHERE CLAY STRATA ARE INVOLVED.

GREATEST SETTLEMENTS MAY GENERALLY BE EXPECTED AT CENTERS OF LOADED AREAS.

SETTLEMENTS TEND TO INCREASE WITH THE FOLLOWING:

1) SOFTNESS OF THE CLAYEY MATERIAL.
2) THICKNESS OF THE COMPRESSIBLE STRATA.
3) CLOSENESS OF CLAY STRATUM TO GROUND SURFACE.
4) AMOUNT PROPOSED LOADING EXCEEDS PAST LOADING
5) WIDTH OF FOOTING OR LOADED AREA.
6) HEIGHT OF WATER TABLE.
7) LIQUID LIMIT.

SHEAR FAILURES ARE MOST APT TO OCCUR WHEN:
1) FOOTINGS ARE SMALL.
2) SETTLEMENTS ARE LARGE.